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(56) Documents Cited

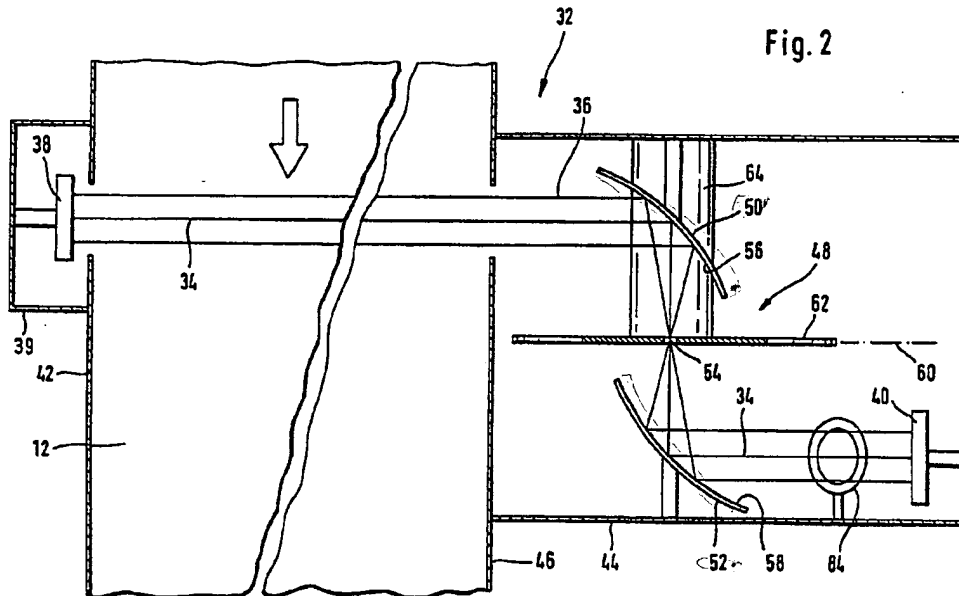
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(58) Field of Search

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(54) Pulsed high-powered laser system

(57) In a pulsed high-powered laser system comprising a resonator 32 with resonator mirrors 38, 40 and with a resonator radiation field 36 extending through an excitable laser medium, a Q-switch 48 determining the laser pulse is arranged in the resonator radiation field and comprises an optical system which forms an image on a line focus 54 and a mechanical chopper 62 effective in the region of the line focus. The optical system comprises two cylindrical, parabolic mirrors 50, 52 arranged confocally to the line focus and reflecting radiation coming from the line focus in opposite directions from each other. The laser beam is uncoupled by an annular scraper mirror 84. The resonator field may have two branches.



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Fig. 1

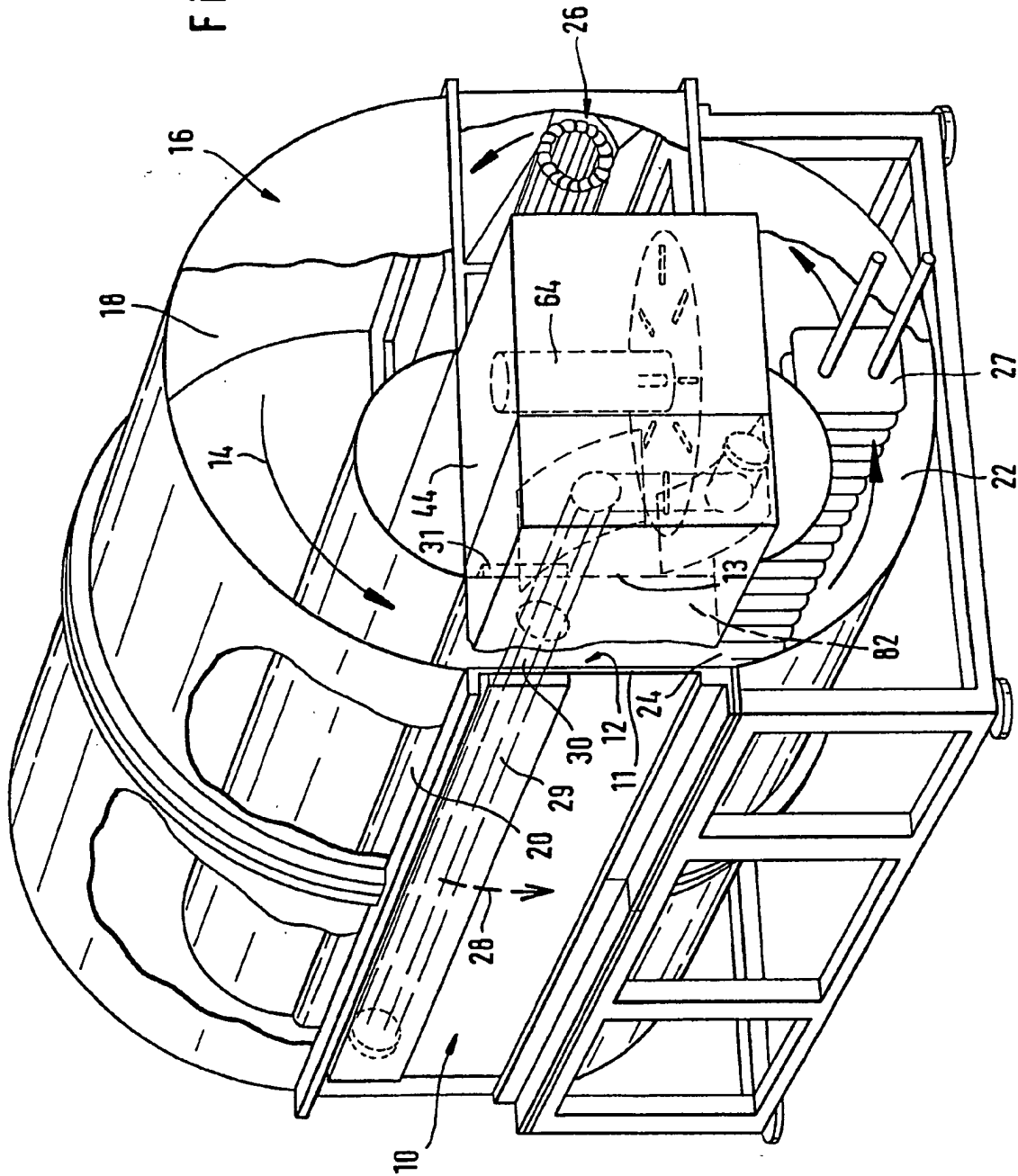


Fig. 2

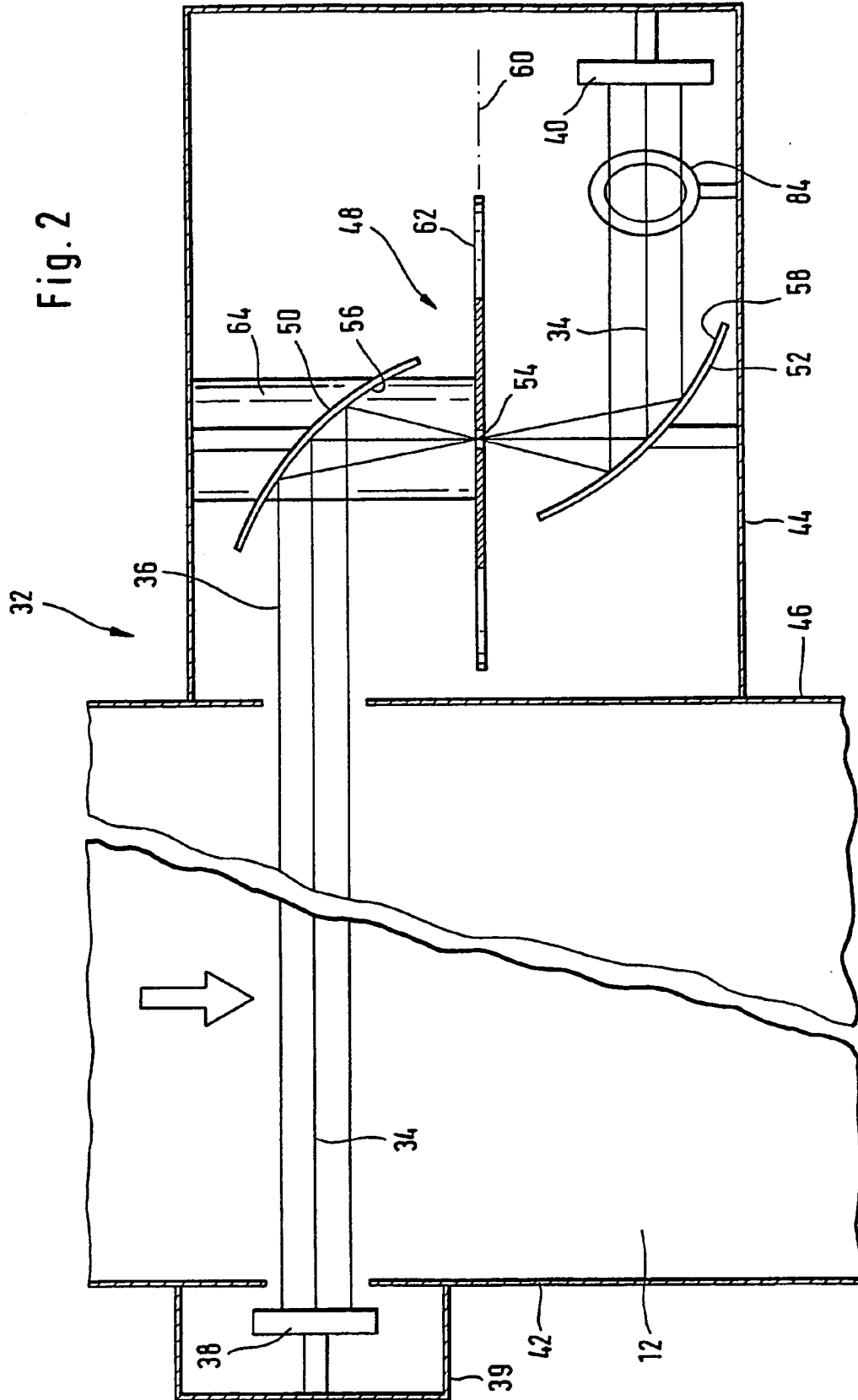


Fig. 3

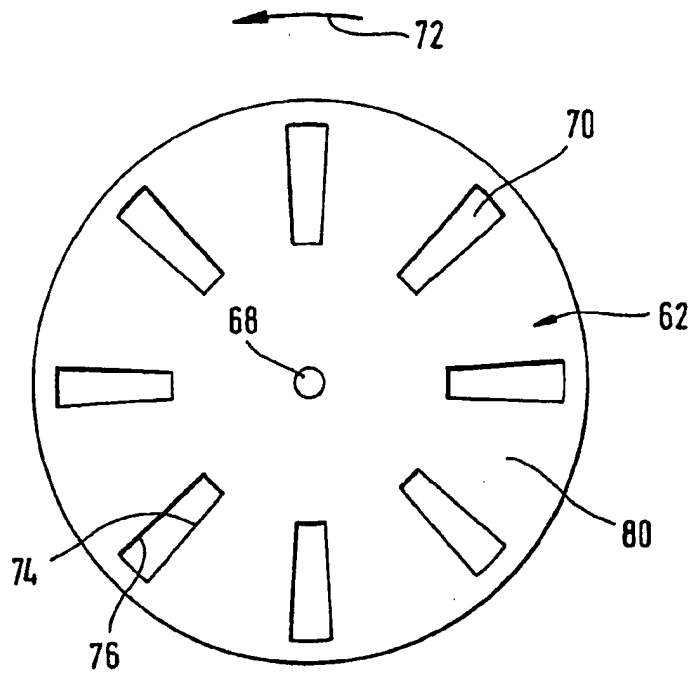
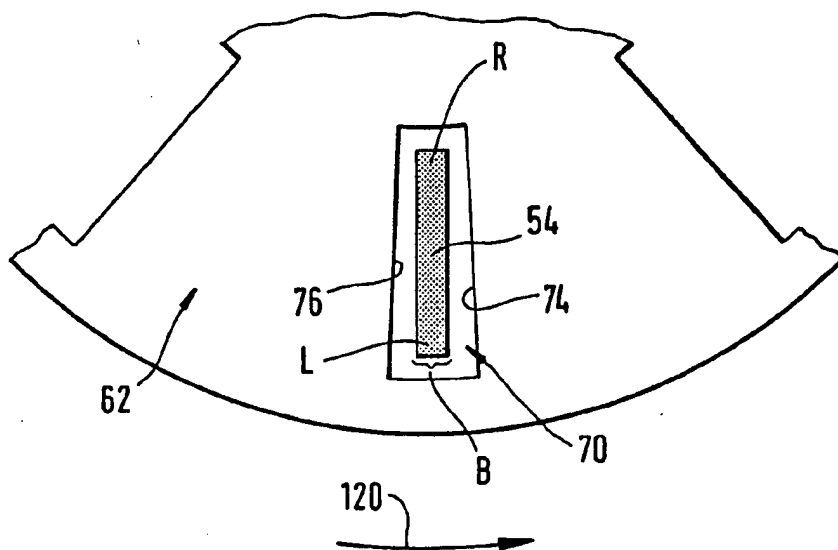


Fig. 5



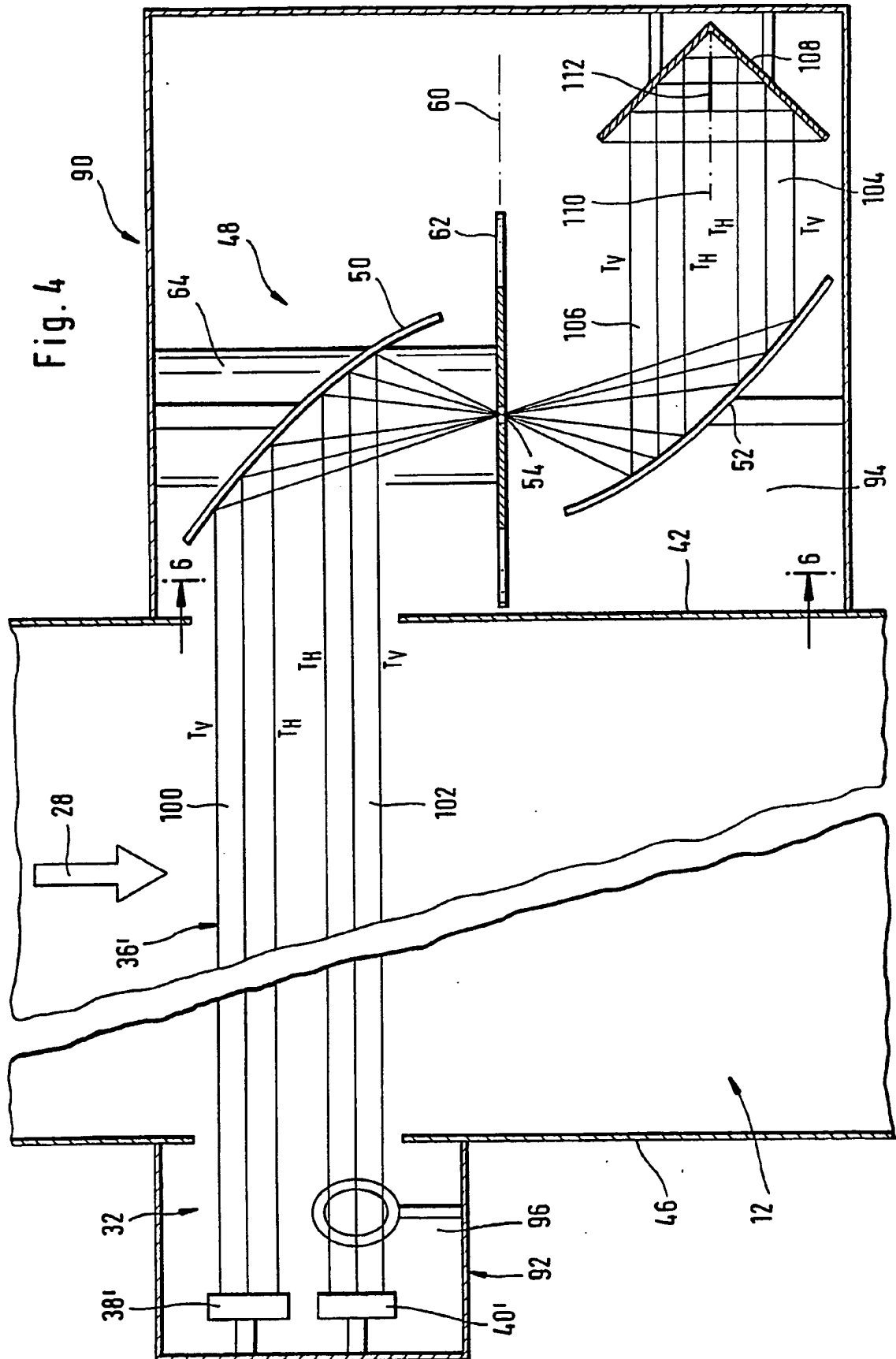
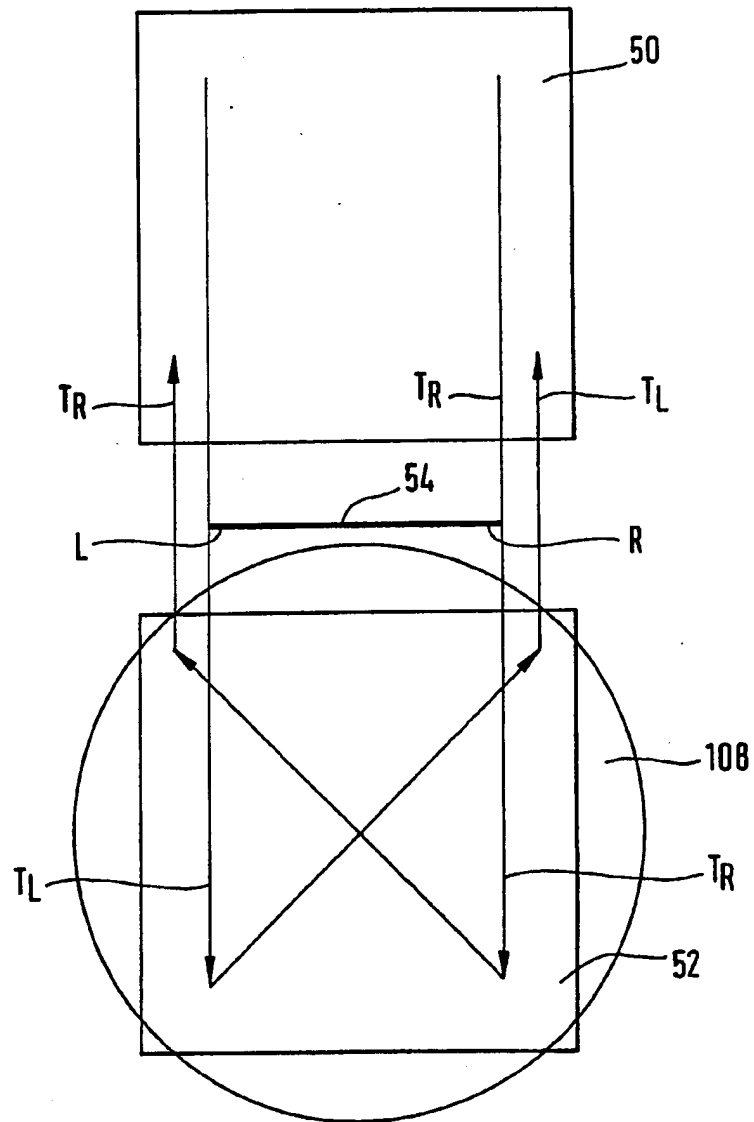


Fig. 6



PULSED HIGH-POWERED LASER SYSTEM

The invention relates to a pulsed high-powered laser system comprising a resonator with resonator mirrors and with a resonator radiation field extending between the resonator mirrors, and an excitable laser medium with the resonator field passing through it.

In known pulsed high-powered laser systems there is the problem that the highest possible occupation inversion density has to be built up to produce the highest possible pulse outputs.

However the build-up of such a high occupation inversion density is prevented by the fact that laser activity starts up automatically from a given magnitude of occupation inversion, so a higher occupation inversion density cannot then be achieved.

The problem underlying the invention is to provide a pulsed high-powered laser system wherein the simplest possible Q-switching is effected to produce the highest possible occupation inversion density.

In a pulsed high-powered laser system of the type described above this problem is solved, according to the invention, in that a Q-switch determining the laser pulse is arranged in the resonator radiation field and has an optical system which forms an image of the resonator radiation field on a line focus and a mechanical chopper effective in the region of the line focus, and that the optical system which forms an image of the resonator radiation field on the line focus comprises two cylindrical, parabolic mirrors arranged confocally to the line focus and reflecting radiation coming from the line focus in opposite directions from each other.

The solution according to the invention, using a line focus with a mechanical chopper wheel, enables the most effective possible Q-switching to be carried out, this being possible without any

problems even at high outputs owing to the distribution of output over the line focus; and secondly, the arrangement of the

5 two parabolic mirrors so that they reflect radiation coming from the line focus in opposite directions causes compensation of distortions of the resonator radiation field to be compensated (sic) by the varying curvature of the parabolic mirrors.

It is favourable for the parabolic mirrors to have the same depth of focus; this is desirable particularly when a cross-section of the resonator radiation field is to be maintained unchanged.

10 In the event of a cross-section of the resonator radiation field having to be made larger or smaller, a particularly advantageous example of the invention provides for the parabolic mirrors to have different depths of focus. In this way adaptation of the
15 resonator radiation field to particular desired cross-sections can necessarily be made by the parabolic mirrors required to produce the line focus, without any additional optical means.

20 Special advantages are obtained when the resonator has a deviation mirror at one side of the Q-switch, the mirror reflecting radiation coming from the Q-switch back to the Q-switch in a parallel offset position and preferably being a conical mirror. The deviation mirror enables the discharge
25 chamber to have two branches of the resonator radiation field passing through it, thereby utilising the available volume to the optimum.

30 In this case it is still more advantageous for the resonator radiation field to pass through the Q-switch twice, since this provides an opportunity of compensating for so-called "switching errors" of the Q-switch.

35 This is possible particularly when the resonator radiation field passes through the line focus more than once. It is then especially desirable for the partial radiation fields of the

resonator radiation field to pass through the line focus during the second passage in a different portion thereof from that used during the first passage; an inverting deviation mirror in particular can cause the partial radiation fields which are at an end portion of the line focus during the first passage to be at the opposite end portion thereof during the second passage. Compensation for the switching speed dependent on the radius of the disc is then possible.

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Where laser gas is used as the laser medium the radiation quality of high-powered lasers according to the invention is limited owing to the varying, i.e. diminishing density of the laser medium in the direction of flow, with the result that the gradient of the optical path length leads to tipping of the laser beam and impoverishment of radiation quality when different partial radiation fields of the resonator radiation field are adjacent one another transversely to the resonator axis. It is therefore particularly advantageous for the resonator radiation field to be taken through the laser medium in such a way that different optical path lengths of partial radiation fields of the resonator radiation field are reduced.

20 A resonator radiation field as provided by the invention is made up of a plurality of partial radiation fields adjacent one another in their direction of propagation and has a finite cross-sectional area transversely to the particular direction of propagation. A resonator radiation field may, for example, 25 comprise a plurality of partial radiation fields adjacent one another in one common direction of propagation, or partial radiation fields defined by reflection back and forth between two mirrors.

30 It is particularly advantageous for the different optical path lengths of the partial radiation fields substantially to be compensated for.

This can be done especially advantageously when the high-powered laser system has two discharge chambers with the resonator radiation field passing through them, the discharge chambers preferably being identical.

5 It is then particularly desirable for the discharge chambers to have gas discharges with identical discharge conditions, preferably an identical density varying in the direction of flow.

10 In this case the resonator radiation field preferably has a structure such that it passes through the discharge chambers in such a way that the effects of the different optical path lengths on the resonator radiation field substantially compensate for each other.

15 Such compensation for the optical path length may take place in many different ways. Thus in a simple alternative embodiment of the invention each discharge channel has one branch of the resonator radiation field passing through it; if the directions of flow are the same, the partial radiation fields of the two branches are turned through 180° from each other about the optical axis, or if there are contrary directions of flow the
20 partial radiation fields pass through the discharge channels without being turned about the optical axis.

25 In a particularly efficient example a discharge channel has two branches of the resonator radiation field passing through it, the two branches particularly being substantially parallel with each other.

30 Other features and advantages of the invention are the subject of the following description and of the accompanying drawings of some examples. In the drawings:

Fig. 1 is a diagrammatic perspective view of a first example,

Fig. 2 is a plan view of the Fig. 1 example from the front,

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Fig. 3 is a plan view of a chopper wheel in the first example,

Fig. 4 is a plan view of a second example from the front, similar to Fig. 2,

Fig. 5 is a fragmentary enlargement of the line focus in a slot-like aperture in the chopper wheel, and

5 Fig. 6 is a diagrammatic representation of conditions in a section taken along the line 6-6 in Fig. 4.

A first example of a high-powered laser according to the invention, shown in Figs 1 to 3, comprises a discharge housing
10 shown generally at 10 which contains a discharge channel 12. A gas stream 14 from a gas circulating system shown generally at 16 passes through the channel 12. The gas circulating system has a supply channel 18 leading to an inflow port 20 of the discharge channel 12, and an outflow channel 22 leading from an outflow
15 port 24 of the discharge channel 12 to a blower shown generally at 26, and causing the laser gas removed to pass through a gas cooler 27.

The stream 14 of laser gas flows through the whole discharge
20 channel 12 in a direction 28 parallel with the side walls 11 and 13 of the channel 12. These walls are either themselves in the form of electrodes to generate a gas discharge in a discharge chamber 30 or alternatively carry electrodes 29 and 31, which are connected to a high frequency source (not shown) to generate a
25 high frequency gas discharge.

A resonator shown generally at 32 in Fig. 2, with an axis 34, extends transversely to the direction of flow 28. A resonator radiation field 36 forms along the axis 34 and extends between
30 end mirrors 38 and 40 of the resonator 32.

A first end mirror 38 is held in a housing 39 on a first face 42 of the discharge channel 12, and the second end mirror 40 is

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arranged at an opposing side of the channel 12 and held in a housing 44, which adjoins a face 46 of the channel 12 opposite the face 42. A Q-switch shown generally at 48 is provided in the housing 44 between the end mirror 40 and the face 46. The Q-switch comprises an image-forming optical system made up of two cylindrical parabolic mirrors 50 and 52, which are arranged at opposite sides of a line focus and confocally thereto, both parabolic mirrors 50 and 52 having cylindrical mirror surfaces 56 and 58, each in the same cylinder direction. The cylinder direction of these mirror surfaces 56 and 58 is parallel with the direction in which the line focus 54 extends.

The two parabolic mirrors 50 and 52 are arranged so that they reflect radiation coming from the line focus 54 in opposite directions.

A chopper wheel 62, which forms part of the Q-switch 48 and can be driven by a drive 64, extends in a plane 60 passing through the line focus 54.

As shown in Fig. 3, the chopper wheel 62 has a plurality of slot-like apertures 70 arranged at an equal radial spacing from an axis of rotation 68; as seen in a rotary direction 72, these apertures have a leading edge 74 and a trailing edge 76, preferably extending radially of the axis of rotation 68. The slot-like apertures 70 are arranged so that they either expose the line focus 54 or cover it, thereby either exposing the resonator radiation field 36 passing through the Q-switch 48 or blocking it with portions 80 located between the slot-like apertures, so that the field 36 is no longer formed between the end mirrors 38 and 40.

The chopper wheel 62 is seated directly on a drive shaft of the drive 64, which is in turn held in the housing 44.

An interior 82 of the housing 44 is preferably directly connected to the discharge chamber 30 by the face 46, so that there are the

same pressure conditions and the same gas in the interior 82 as in the chamber 30. From the point of view of fluid mechanics the interior 82 so to speak forms a dead space, since it adjoins the discharge channel 12 at its face, is under the same pressure and has nothing flowing through it.

5 A laser beam is uncoupled from the resonator radiation field 36 by means of an annular scraper mirror 84, which may be arranged e.g. in front of the end mirror 40 and which reflects an annular external partial radiation field of the resonator radiation field 36 perpendicularly to the resonator axis 34.

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In a second example illustrated in Fig. 4 the discharge channel 12 and the gas circulating system 16 are of the same construction as in the first example, so they and all their contents can be referred to here.

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In contrast with the first example the two end mirrors 38' and 40' of the resonator 32' are arranged at one side of the discharge channel 12, while the Q-switch 48' is arranged at the opposite side of the channel 12 and surrounded by a Q-switch

20 housing 90.

The Q-switch housing 90 adjoins the face 46 of the discharge channel 12. In the same way the two end mirrors 38' and 40' are arranged in a mirror housing 92 adjoining the face 42 of the
25 channel 12.

Both an interior 94 of the Q-switch housing 90 and an interior 96 of the mirror housing 92 are connected to the discharge channel 12, so that there are the same pressure and gas conditions in the
30 housings 90 and 92 as in the channel 12, except that the gas stream 14 does not flow through the interiors 94 and 96 thereof in the direction 28.

In the same way as in the first example the Q-switch 48' comprises two cylindrical parabolic mirrors 50 and 52, arranged

confocally to the line focus 54 and forming an image of the resonator radiation field 36' thereon.

In contrast with the first example the resonator radiation field 36' comprises a first branch 100 passing through the discharge chamber 30, and a second branch 102 passing through that chamber; both are focused on the same line focus 54 by the parabolic mirror 50 and are coupled in the opposite direction, as branches 104 and 106, with branches 100 and 102 respectively by the parabolic mirror 52. These branches 104 and 106 are coupled together by a conical mirror 108, the axis 110 of the cone extending parallel with the branches 106 and 104 and preferably midway between them. Hence the conical mirror 108 couples the branch 104 to the branch 106 and thus indirectly couples together the branches 102.

Like the Q-switch 48 described in detail in connection with the first example, the Q-switch 48' in the second example comprises the chopper wheel 62 driven by the drive 64; it is the same shape as in the first example and is in the plane 60.

When the portion 80 of the chopper wheel 62 covers the line focus 54, the branches 104 and 106 are separated from the branches 100 and 102, whereas when the line focus is exposed the branches 100 and 102 are indirectly coupled together by the conical mirror 108; the mirror 108 also forms images of the branches 104 and 106 by means of a line focus 112, and partial radiation fields of the branches 100 and 102 are thus indirectly coupled together by the conical mirror 108. Partial radiation fields of the branches 100 and 102 are inverted relative to one another through the formation of images of the branches 104 and 106 by means of the line focus 112, as will be explained below.

Considering the partial radiation field T_v which is in front in the direction of flow 28, and the partial radiation field T_r which is behind it in the branch 100, their position is inverted by the two parabolic mirrors 50 and 52 and the conical mirror

180, so that the field T_v in the branch 102 is behind in the direction of flow 28, and the field T_r is in front in the branch 102 and in the direction of flow 28.

5 This makes it possible to reduce a gradient of optical density which forms when gas is discharged in the direction of flow 28, for the optical density diminishing in the direction of flow has the effect that the partial radiation field T_v in the branch 100 passes through a greater optical density than the field T_r in the branch 100. As a result of their reversal in the branch 102 the
10 field T_r thereupon passes through the greater optical density, while the field T_v passes through the still lower optical density; the difference in optical path length between the fields T_v and T_r is thus reduced.

15 The line focus 54 has a finite width B in the peripheral direction of the chopper wheel 62 as illustrated in Fig. 5. Hence there is either an irregular exposure of the line focus 54 by the leading edge 74 or an irregular covering of the line focus by the trailing edge 76 if these extend e.g. radially of the axis
20 of rotation 68, since a left-hand portion L and a right-hand portion R of the line focus 54 are either exposed or covered at different times, if the resonator radiation field only passes through the Q-circuit 48 once.

25 This is compensated for in the second example of the invention as will be seen from Fig. 6.

A left-hand partial radiation field T_l of the branch 100 is reflected through the line focus 54 unchanged, by the parabolic
30 mirrors 50 and 52, with the left-hand field T_l passing through the left-hand portion L of the line focus 54 during the first passage. As a result of the reversal of conditions by the conical mirror 108, when the left-hand partial radiation field T_l is reflected back by the parabolic mirrors 52 and 50 during the second passage through the line focus 54, it will pass through the right-hand portion thereof, thereby compensating for

differences between the covering or exposure of the left or right-hand portion of the line focus 54. The same applies to a right-hand partial radiation field T_r in the branch 100. It passes through the right-hand portion of the line focus 54, and
5 when it is reflected back by the parabolic mirrors 52 and 50 after inversion it passes through the left-hand portion thereof.

All in all, as a result of the inversion of the resonator radiation field 36' during the second passage through the line
10 focus 54 relative to the first passage through the line focus 54, compensation for unequal covering or exposure of the line focus 54 by the leading edge 74 or the trailing edge 76 of the slot-like apertures 70 in the chopper wheel 62 is compensated for (sic).

15 In both examples the laser operates so that both pulse duration and intervals between laser pulses can be preset by the rotating chopper wheel 62 and by the width B of the apertures 70 and the width of the portions 80 in the rotary direction 120, with
20 initiation of laser activity being suppressed during the intervals between pulses.

The laser gas is excited in the usual, known manner in both examples, preferably by means of a high frequency discharge in
25 the case of known laser gas mixtures for transverse-flow lasers, for example CO_2 with the usual additives; appropriate high frequency is coupled in for this purpose, in a manner known from prior art.

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C L A I M S

1. A pulsed high-powered laser system comprising a resonator with resonator mirrors and with a resonator radiation field extending between the resonator mirrors, and an excitable laser medium with the resonator field passing through it, characterised
5 in that a Q-switch (48) determining the laser pulse is arranged in the resonator radiation field (36) and has an optical system (50, 52) which forms an image of the resonator radiation field (36) on a line focus (54) and a mechanical chopper (62) effective in the region of the line focus (54), and that the optical system
10 (50, 52) which forms an image of the resonator radiation field (36) on the line focus (54) comprises two cylindrical, parabolic mirrors (50, 52) arranged confocally to the line focus (54) and reflecting radiation coming from the line focus (54) in opposite directions from each other.
- 15 2. A laser according to claim 1, characterised in that the parabolic mirrors (50, 52) have the same depth of focus.
- 20 3. A laser according to claim 1, characterised in that the parabolic mirrors (50, 52) have different depths of focus.
- 25 4. A laser according to any of the preceding claims, characterised in that the resonator (32) has a deviation mirror (108) at one side of the Q-switch (48), the mirror reflecting radiation coming from the Q-switch back to the Q-switch in a parallel offset position.
- 30 5. A laser according to claim 4, characterised in that the resonator radiation field (36) passes through the Q-switch (48) twice.
6. A laser according to claim 5, characterised in that the partial radiation fields (T_1 , T_2) pass through the line focus (54)

during the second passage in a different portion (R, L) thereof from that used during the first passage.

- 5 7. A laser according to any of the preceding claims, characterised in that the resonator radiation field (36) is taken through the laser medium in such a way that different optical path lengths of partial radiation fields (T_v , T_s) of the resonator radiation field (36) are reduced.

13.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
 GB 9318086.7

Relevant Technical Fields

- (i) UK Cl (Ed.L) H1C (CBBB CEB CEX)
 (ii) Int Cl (Ed.5) H01S

Search Examiner
 R C HRADSKY

Date of completion of Search
 3 NOVEMBER 1993

Databases (see below)

- (i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-
 1-7

(ii)

Categories of documents

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| <p>X: Document indicating lack of novelty or of inventive step.</p> <p>Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.</p> <p>A: Document indicating technological background and/or state of the art.</p> | <p>P: Document published on or after the declared priority date but before the filing date of the present application.</p> <p>E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.</p> <p>&: Member of the same patent family; corresponding document.</p> |
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Category	Identity of document and relevant passages	Relevant to claim(s)
	None	

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